A DOE SUCCESS: Automated Disassembly of Explosive Gas Generators

The Project: Many of the thousands of nuclear weapons that are being retired by the United States contain components known as explosive gas generators. When these components are removed from nuclear weapons, they must be demilitarized. Traditionally, demilitarization has been handled by igniting generators at a burning ground, but this process is potentially hazardous because the depletion of a stabilizer in the propellant (which occurs naturally over time) poses a risk of accidental ignition, as does the cleanup of unburned propellant. In addition, the resulting waste stream is contaminated by lead and propellant residue. Disassembly is an alternative demilitarization process, but manual disassembly of gas generators has an even higher potential for accidental ignition and possible serious injury. Neither demilitarization option was viable.

Automated disassembly was an obvious consideration because it could ensure operator safety while yielding uncontaminated products (most of which can be recycled), but had never been attempted for this type of component. The disassembly steps are simple but numerous—removing a threaded locking ring, removing a closure disc, pouring out the propellant, dislodging any remaining propellant, removing a threaded igniter, and placing the igniter in a pallet. In addition, not only must the components be handled very gently, but the generators were not designed for automated assembly or disassembly. A further complication was that there are a number of different designs in the nuclear stockpile and it was desirable that any disassembly system be able to rapidly and cost effectively change among the different designs. Such flexibility is difficult for any automated system, but is doubly difficult when strict safety standards must be followed. All these factors had to be taken into consideration in the design of the disassembly system.

Automated disassembly requires the workcell to align various wrenches with components, unscrew threaded components, pour propellant, clean out propellant that does not pour freely, and handle sensitive igniters. Sounds like simple tasks for a human, but it was necessary for Sandia National Laboratories' Intelligent Systems and Robotics Center to draw upon its years of work on computer vision, force-controlled motion, and adaptive control to ensure that the force and mechanical shock applied to workpieces were minimal. The integration of these skills is known as dexterous manipulation. Minimal, controlled force and shock are necessary to reduce the potential for accidental ignition of propellant in the gas generator. In addition, the workcell—the Automated Gas Generator Disassembly System (AGGDIS)—uses force control as well as computer vision to accommodate remaining variations in the process.

Although the robot performs most of the handling processes, it cannot deliver the torque required to remove threaded sub-components. A powered socket was developed to provide the needed torque. The robot manipulates specialized wrenches (modified from existing equipment) that incorporate parallel jaw and vacuum grippers to grasp parts as they are removed.

Motion of the robot and the powered socket is closely synchronized by a Programmable Logic Controller that is in communication with the robot controller. From a remote console, the operator controls the AGGDIS system with a graphical push-button interface operating under Windows on a PC. The operator also uses two video cameras—one robot-mounted and one independent pan/tilt/zoom unit—to monitor the workcell operations. Because the design allows control from a remote location, hazards to personnel are reduced. For example, in the event of a processing problem, the operator can safe the area by placing the hazardous components in temporary storage before personnel approach the workcell.

The Impact: AGGDIS performed its first disassembly of a live MC1362 gas generator in April 1997, and completed demilitarizing the backlog of 1,075 of these generators without incident. Without AGGDIS, these explosive components would have remained in storage because there was no other means of disassembly that was safe for workers and/or the environment. Leaving the generators in storage was not an acceptable alternative because they would have continued to age, perhaps to the point of becoming unsafe. At the completion of disassembly of the MC1362 generators, the workcell was then converted to disassemble MC1835 and MC3002 gas generators. These generators are larger and shaped differently than the MC1362, which required fabricating and swapping out alternative tooling, including station tabletops and robot grippers; updating the robot motion paths; updating the software; and checking out the system. The robot motion path and software updates were completed in a mere three days. The workcell has since demilitarized the backlog of more than 1,000 of the MC1835 and MC3002 generators without incident. The workcell remains in service to disassemble gas generators that continue to be removed from weapons.

Further Advances through a RIM Initiative: The next class of explosive components are much more complex than the ones dismantled to date. Improved dexterity will be necessary to remove personnel from this operation. There are thousands of these components as well.

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